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The JPL Hurricane Portal

An Integrated Tropical Cyclone Information System

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AIRS Science Team Meeting; Pasadena, CA; April 15-18, 2008

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Motivation for developing the hurricane information system

- ***In spite of recent improvements in hurricane track forecast accuracy, there are still many unanswered questions about the physical processes that determine hurricane genesis and evolution.***
- ***Furthermore, a significant amount of work remains to be done in validating and improving hurricane forecast models.***
- ***None of this can be accomplished without a comprehensive set of multiparameter observations that are relevant to both the large-scale and the storm-scale processes in the atmosphere and in the ocean.***
- ***Even today, when so many instruments are observing the Earth's atmosphere and oceans, there is no one place where a researcher could easily gather all the information (including data) that pertains to a particular hurricane or an ocean basin.***
- ***JPL is uniquely positioned to accomplish that because of:***
  - Our extensive experience with satellite observations and intimate knowledge about retrieved products, many developed at JPL
  - Our ability to bring observations and models together by developing instrument simulators that use the model output and generate satellite “observables” needed:
    - *for model-data comparisons*
    - *for data assimilation*

Objective

To provide fusion of multiparameter observations **(satellite, airborne and in-situ)** and model output**, relevant to both the large-scale and the storm-scale hurricane processes in the atmosphere and in the ocean** with the purpose of:

- understanding the physical processes that determine hurricane genesis, intensity, track and impact on large-scale environment
- improving the forecast of hurricane track and intensity by facilitating hurricane model validations and data assimilation
- enabling studies aimed at developing new algorithms, sensor systems and missions.

Current Results

Developed a prototype of a comprehensive hurricane information system of high-resolution satellite, airborne and in-situ observations and model outputs pertaining to: i) the thermodynamic and microphysical structure of the storms; ii) the air-sea interaction processes; iii) the larger-scale environment.

i) microphysical parameters – TRMM / CloudSat / MISR / MLS / AIRS / AMSU provide data to determine the cloud and precipitation structure

ii) thermodynamics – AIRS / AMSU / MLS / COSMIC provide temperature and vapor profiles to characterize both the large-scale environment conducive to storm development and the storm-induced perturbations. QuikSCAT surface winds have been determined to be of very high value to the operational forecasters.

iii) air-sea interactions – The global high-resolution OSTIA product of SST estimates from merged satellite and in-situ measurements characterizes the storm's energy source and potential and complements surface wind observations from QuikSCAT to depict the SST-wind interactions.

iv) large-scale environment – MISR and MODIS aerosol data will help shed light on the CCN impact on cloud microphysics and on the recently much discussed question of whether and how atmospheric dust modulates hurricane intensity and frequency.

v) in-situ observations - ocean profiles of temperature in salinity in the top 1000 m as measured by the Argo floats.

vi) model output - high-resolution cloud-resolving model runs from WRF.

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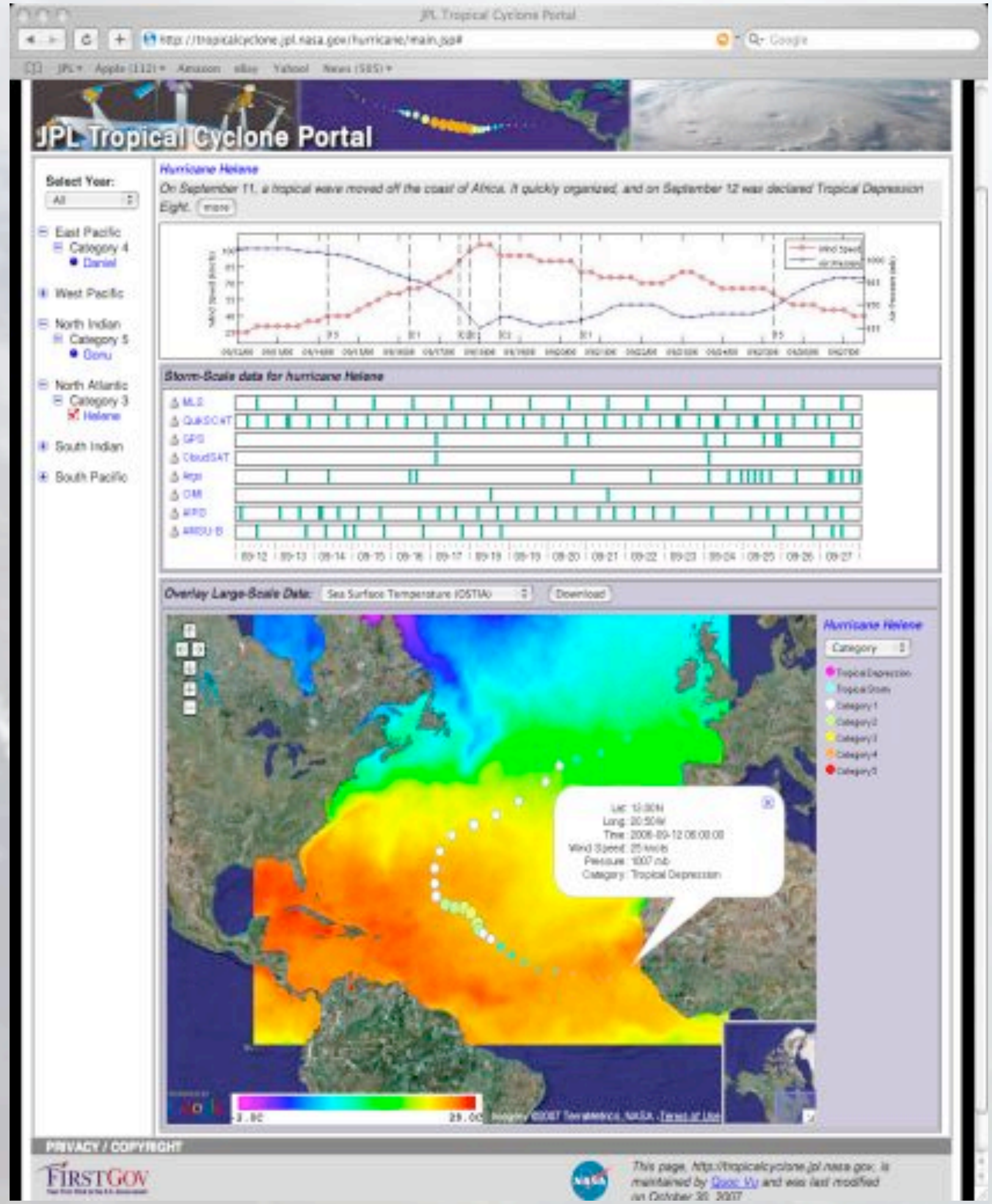

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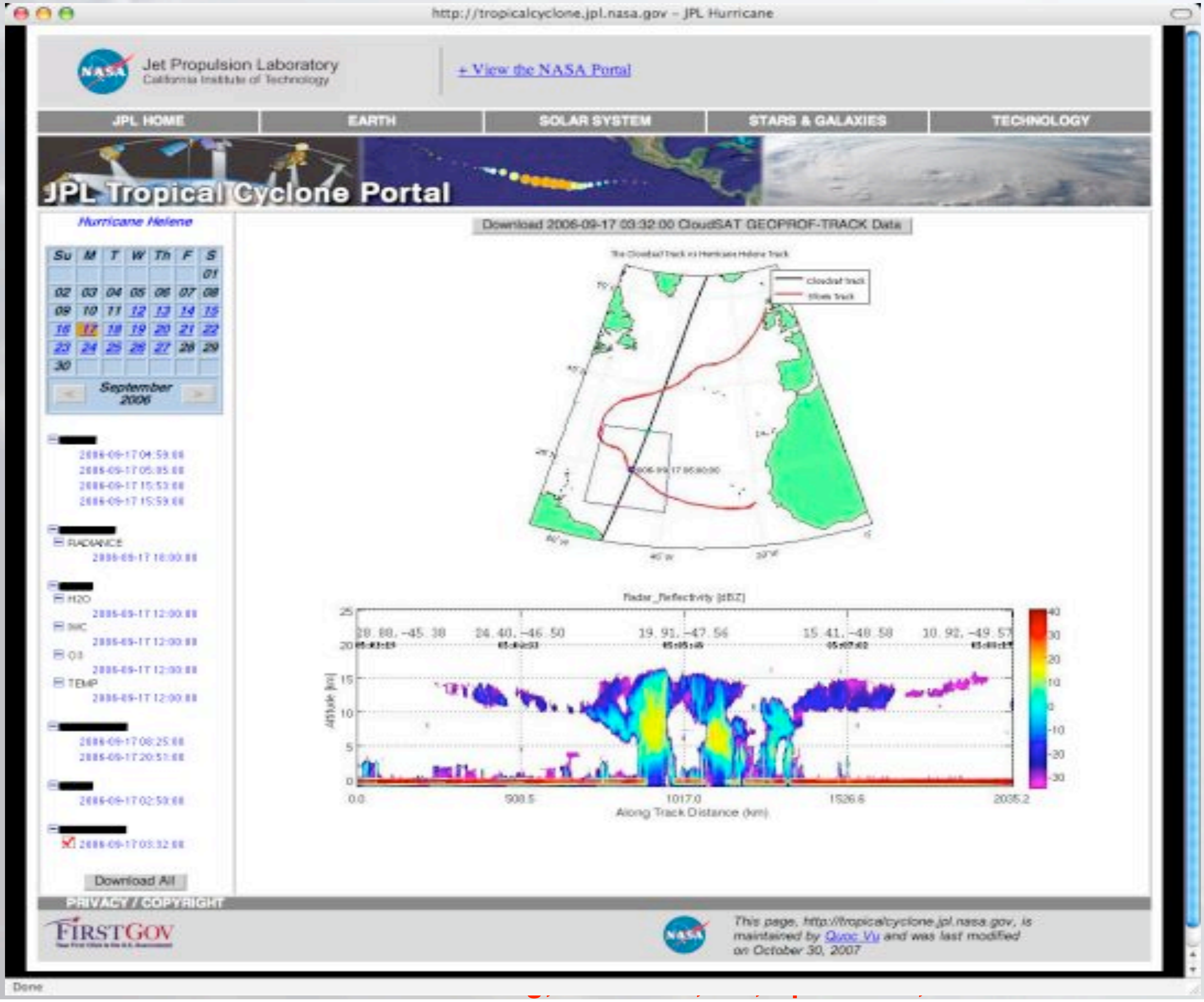

Unique features of our portal:

- ***it is designed to provide a** multitude of observations, together with model output, **that are relevant to both the large-scale and the storm-scale processes in the atmosphere and in the ocean;***
- ***all storm-scale** observations are presented in a common space, centered on the storm;*
- ***data are organized in an** easy way to determine when coincident observations **from multiple instruments are available;***
- *data, in addition to their graphical representation, are obtainable with a click of a button!*
- ***COMING SOON***
    - We are in the process of **developing analysis tools** that will communicate with the database to allow for:
        - comparison of observations from different platforms and instruments;
        - model validation through comparison with observations;
        - development of multiparameter covariances that are needed for data assimilation.
    - **All tropical cyclones of 2005**
    - **Field Campaign data; GOES IR; AMSR-E; SSM/I**

Ongoing development:

High-Resolution Modeling
Model Assessment
Instrument Simulators

Why use WRF to study hurricanes?

WRF is a state-of-the-art model developed collaboratively among several agencies (NOAA/NCEP, NOAA/FSL, NCAR) and with strong participation from the research community.

Designed to study mesoscale and convective scale processes and to provide advanced forecast and data assimilation system for research and operations.

- **multiple nested grids with different spatial resolution to allow resolving both the highly 3D structure of convection and the extensive mesoscale circulations.**
- **use of initial/boundary conditions provided by a larger-scale model, thus, properly reflecting the 3D variability of the large-scale atmospheric structures.**

Can be run as a Cloud-Resolving Model, meaning

- **much better spatial and temporal resolution than the larger-scale models**
- **Using more realistic microphysical parameterizations instead of the larger-scale model convective parameterizations to represent precipitation production and the associated latent heat release that drives the vertical motion and the entire circulation**

Why Cloud-Resolving approach is important for simulating hurricanes.

- **Recent studies suggest that the convection in the hurricane inner core might be of significant importance for determining storm intensity and track. Hence, needed is: high resolution; good representation of the microphysical processes**

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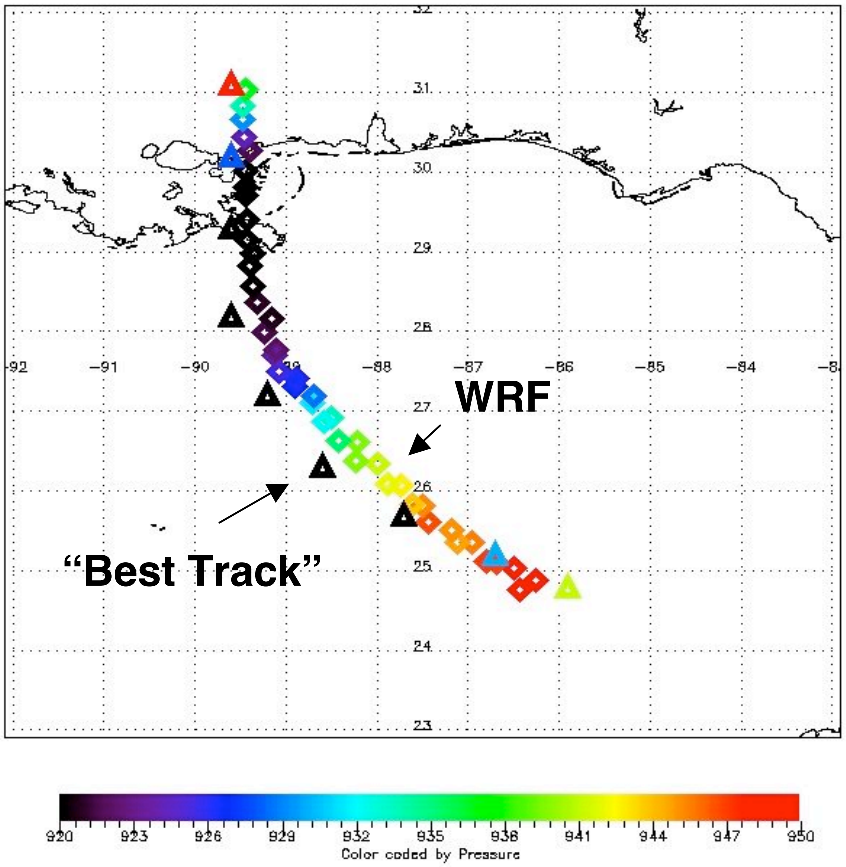
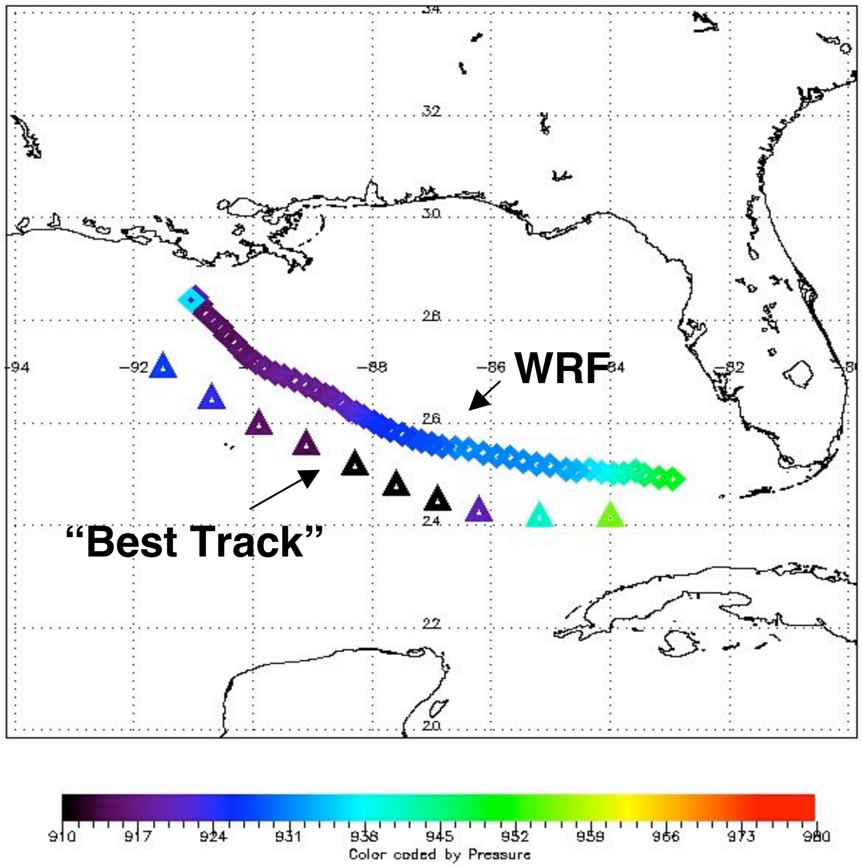
Evaluating WRF ….

Tracks of simulated and observed storms

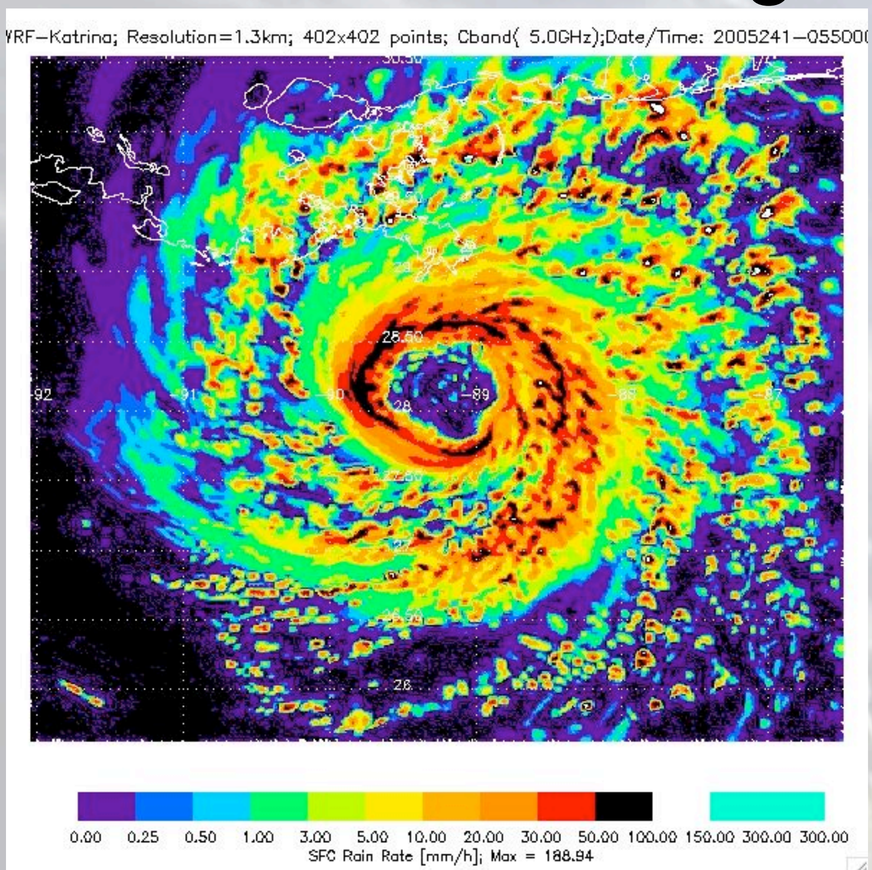
KATRINA - 2005

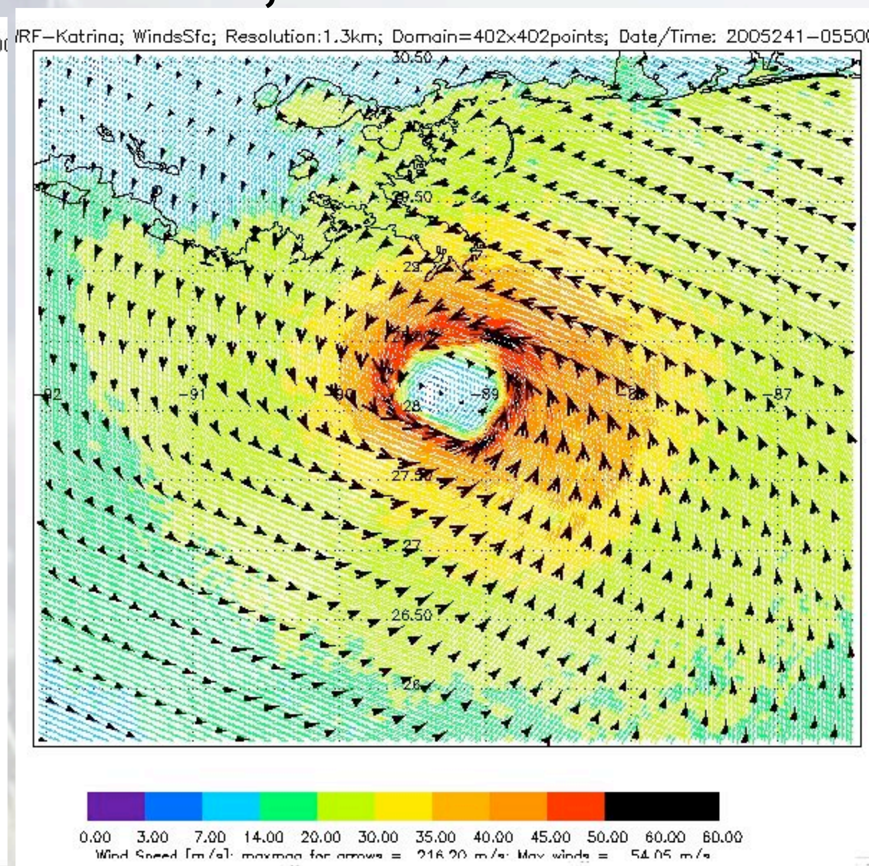


RITA - 2005



WRF simulation of KATRINA - 05:50Z August 29th, 2005





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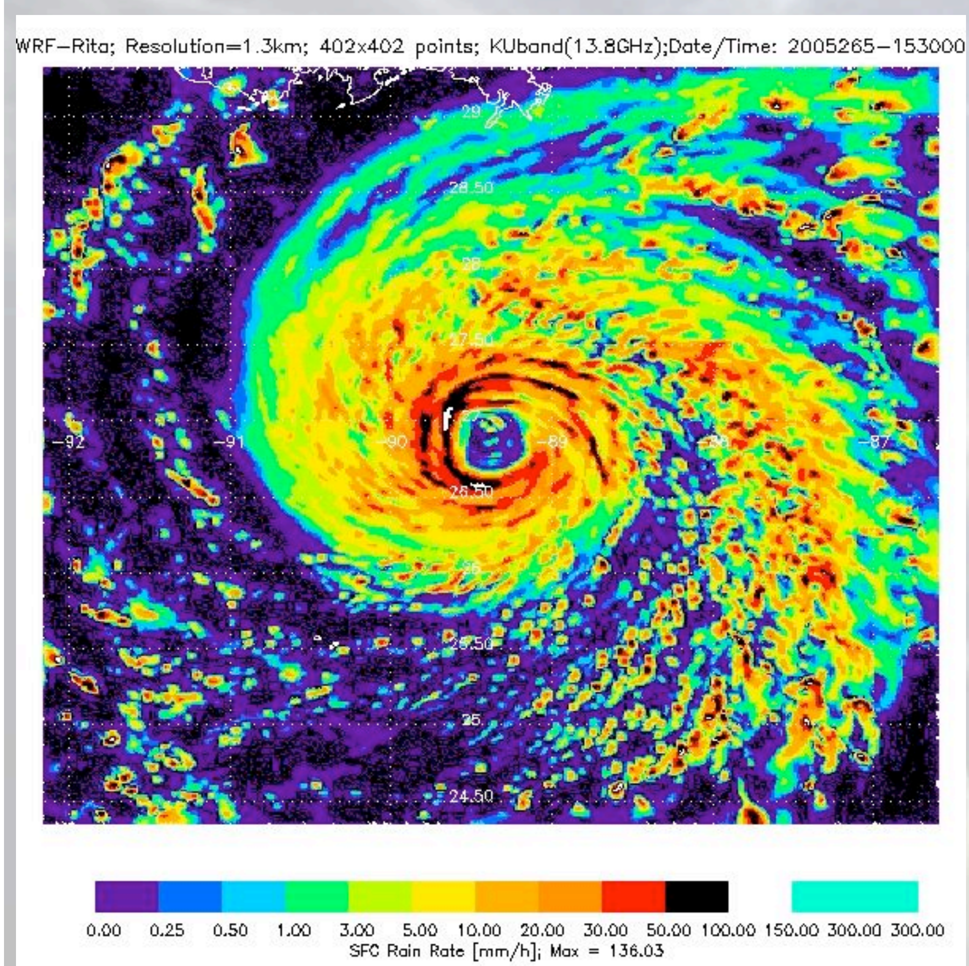
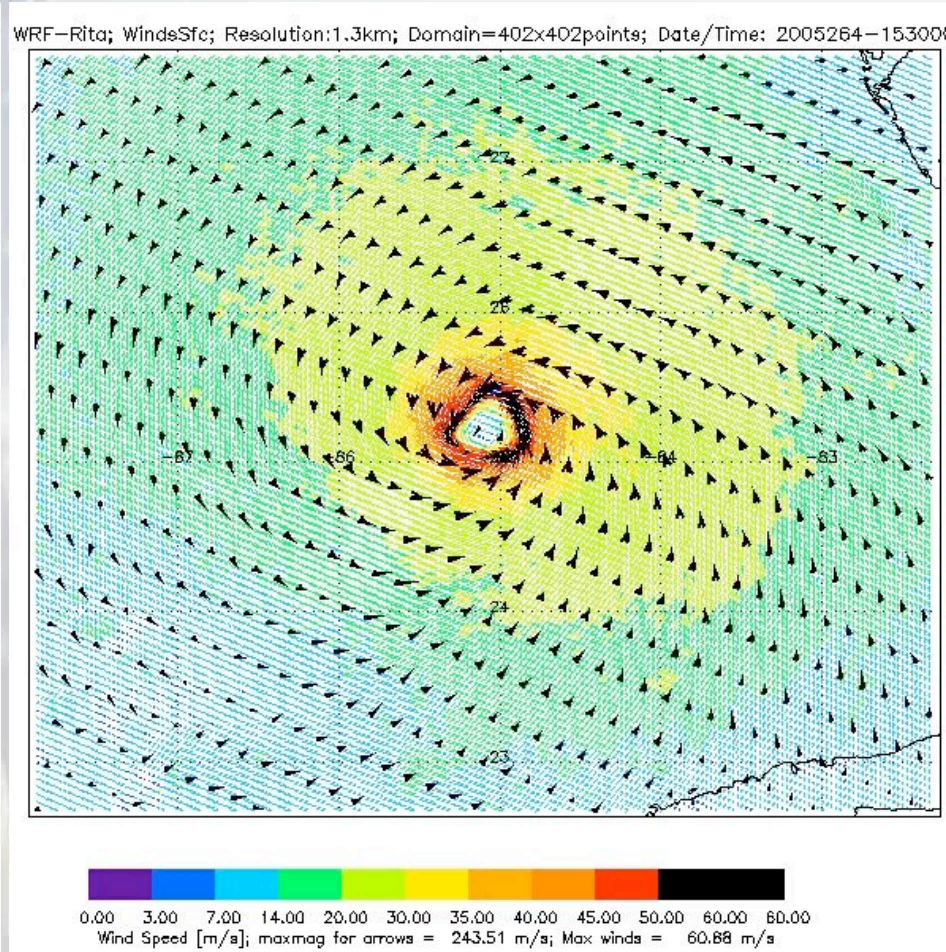
Evaluating WRF ....

WRF simulation of RITA
15:30Z September 22, 2005





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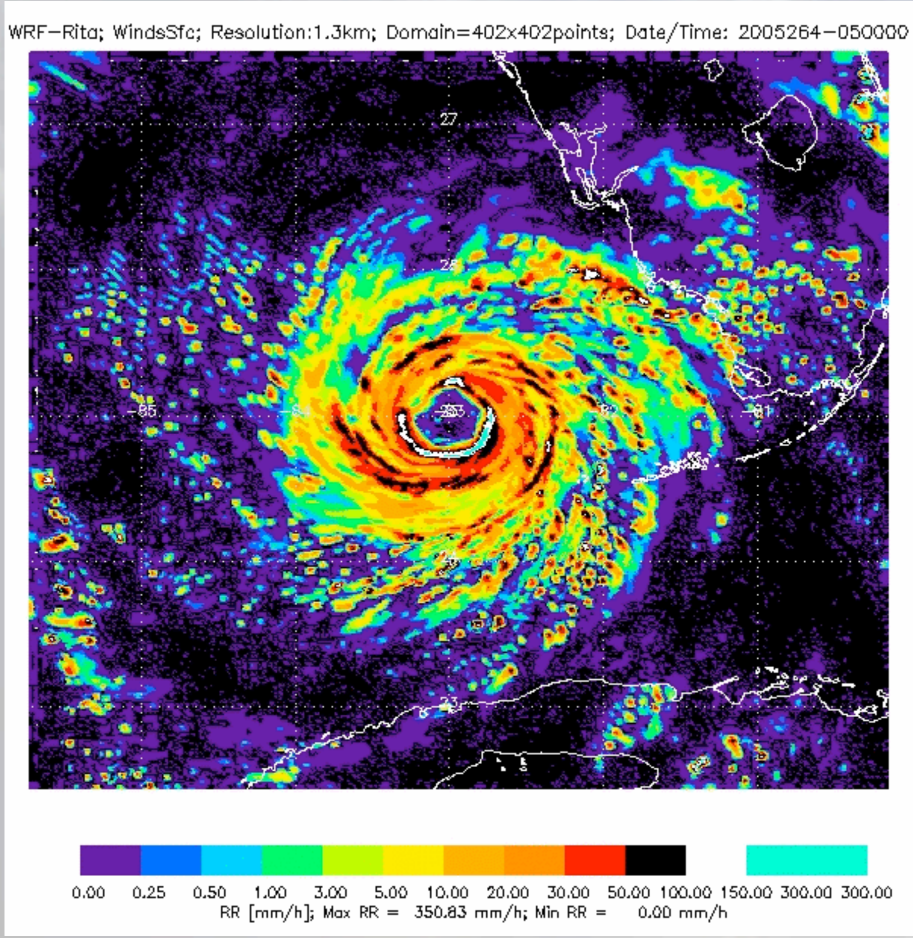
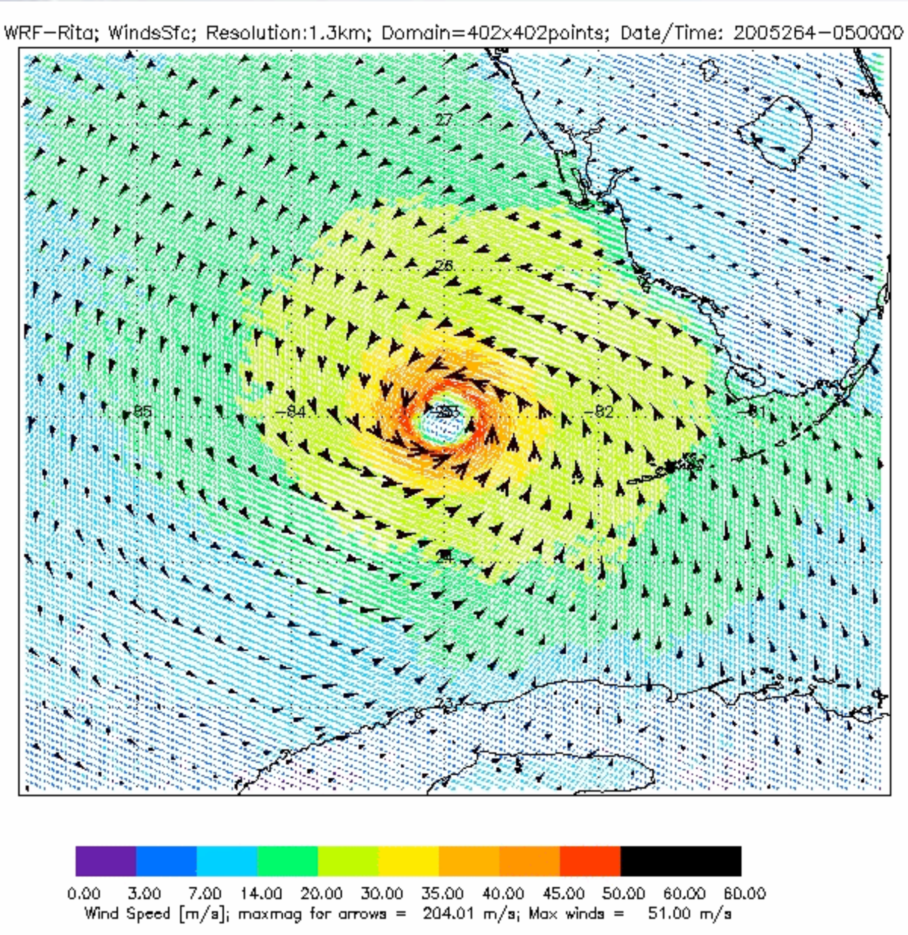
Evaluating WRF ....

WRF simulation of RITA - September, 2005





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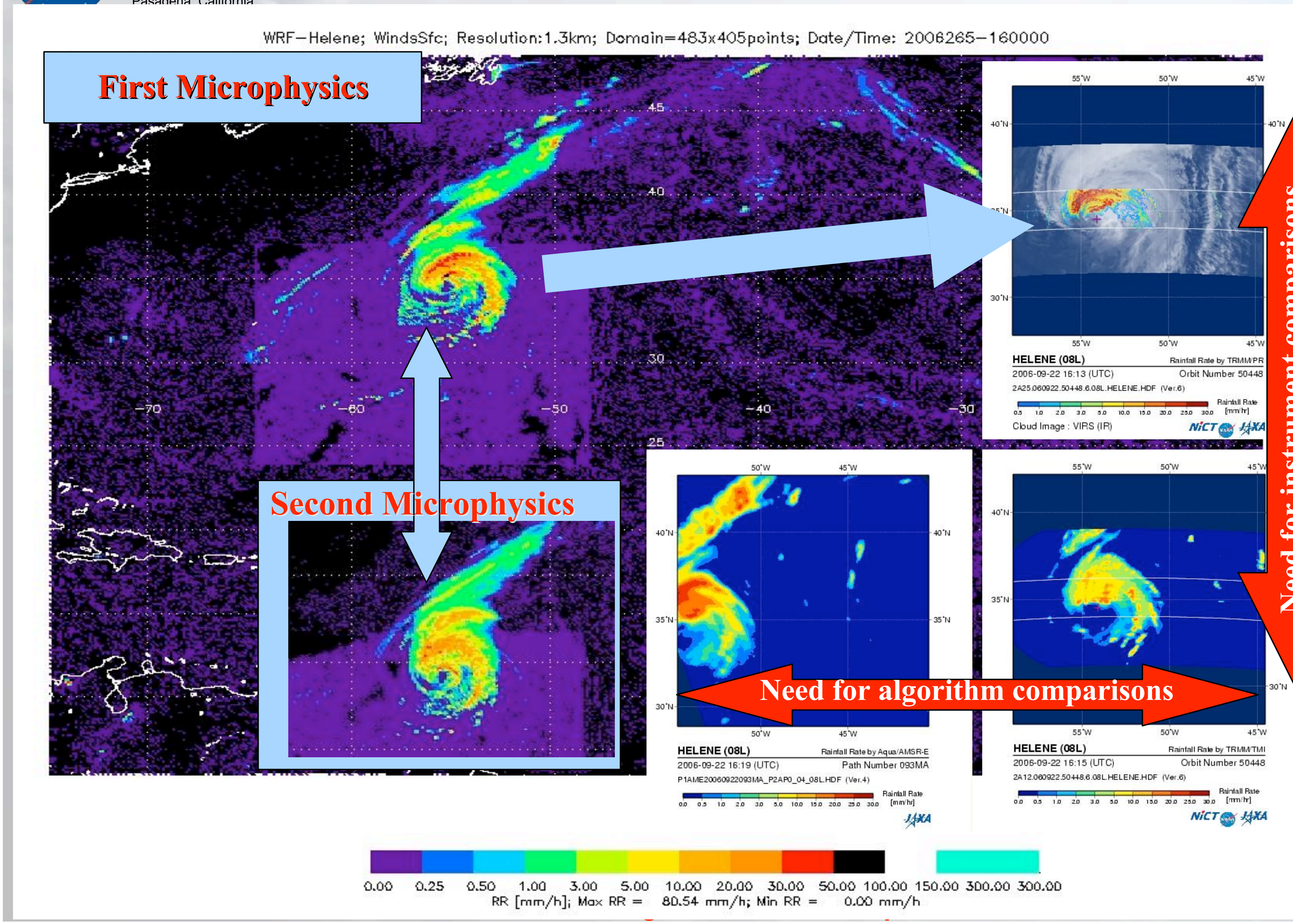
Evaluating WRF ....



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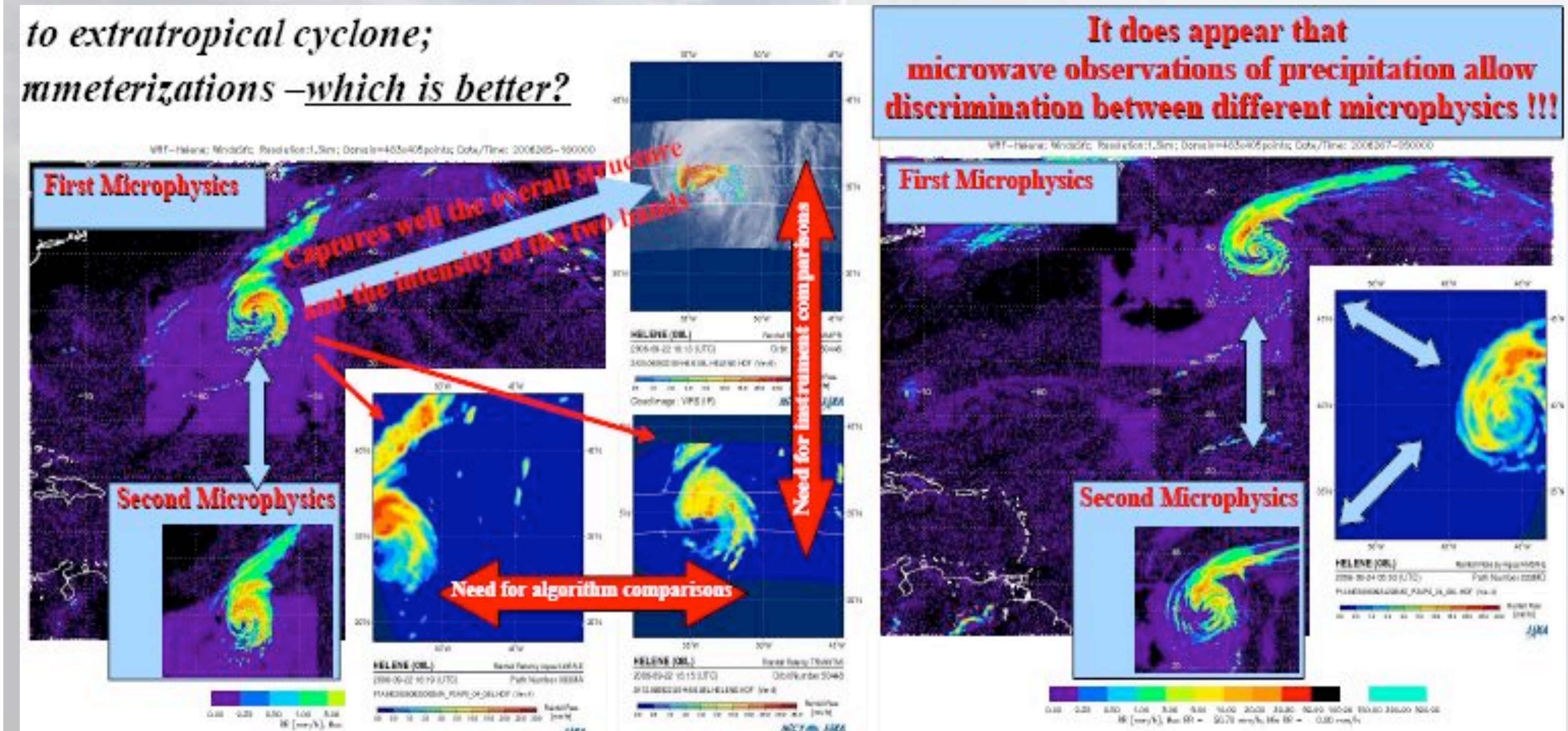

Instrument simulators ....

- **The WRF output fields can be used as input to instrument simulators (e.g. Volume Backscatter, Path Integrated Attenuation, Wind-Induced Sigma0.**
- **Example - simulating the next-generation scatterometer:**
  - *the 10 m wind – input to compute the wind-related sigma0*
  - *the 3D precipitation structure – input to compute the rain-associated contributions to the wind sigma0*
    - **attenuation** (produced by precipitation, cloud and vapor)
    - **volume backscatter** (produced by the precipitation).
    - Mie scattering code was used to compute the attenuation and the volume backscatter at the frequencies and the polarization of the XOVWM instrument. Furthermore, an incidence angle correction was made in the path of the scatterometer signal through the precipitation.

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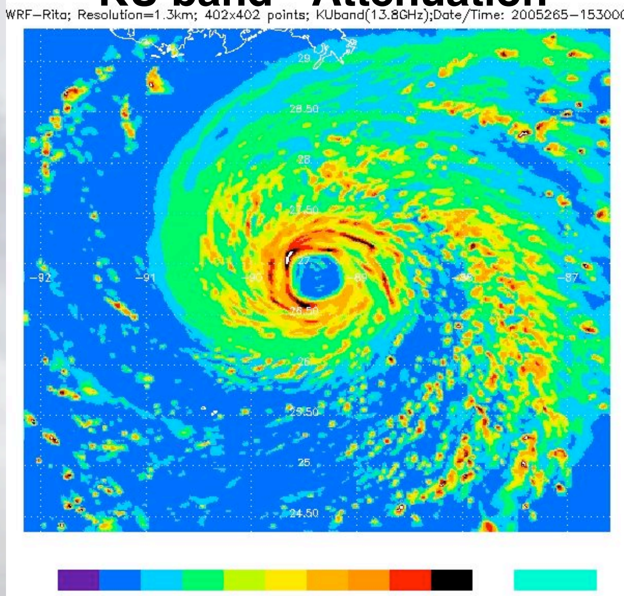
Instrument simulators ....

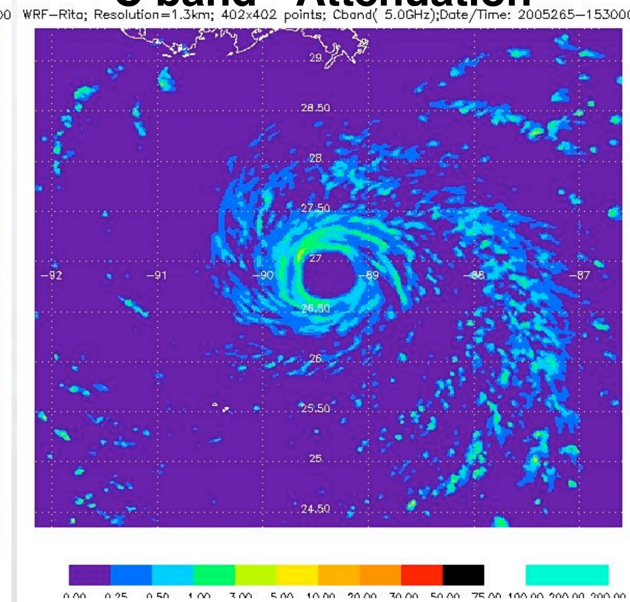
Rain-associated contributions to the wind sigma0

Example from Rita - Sep. 22, 15:30 Z

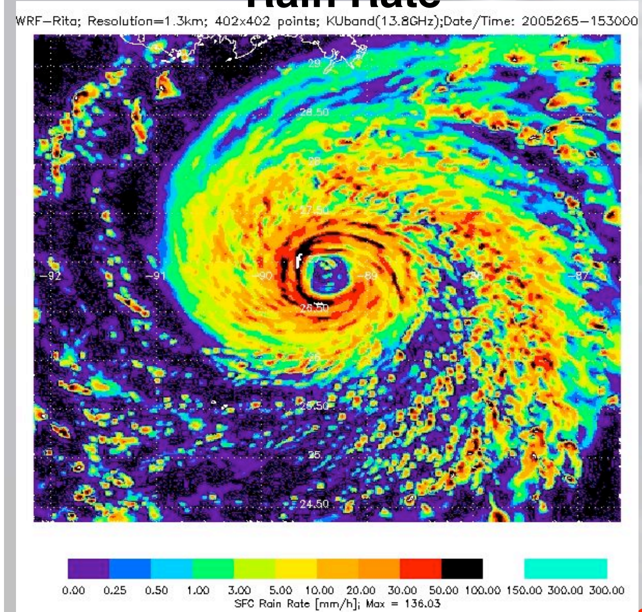
KU band - Attenuation



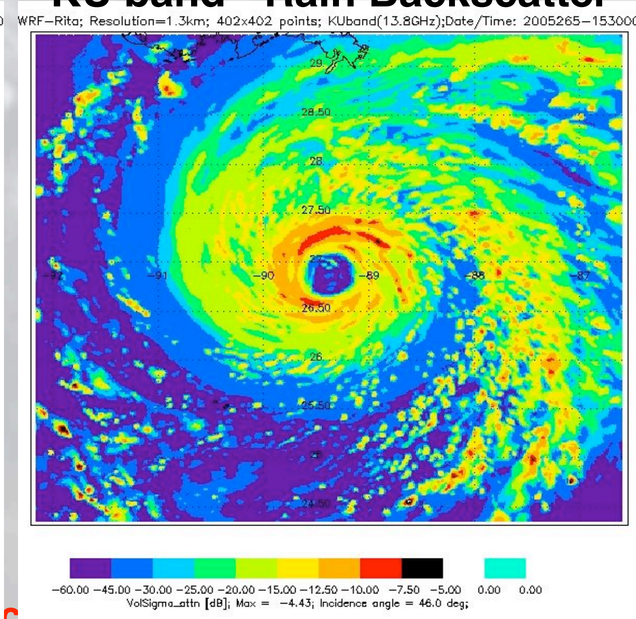
C band - Attenuation



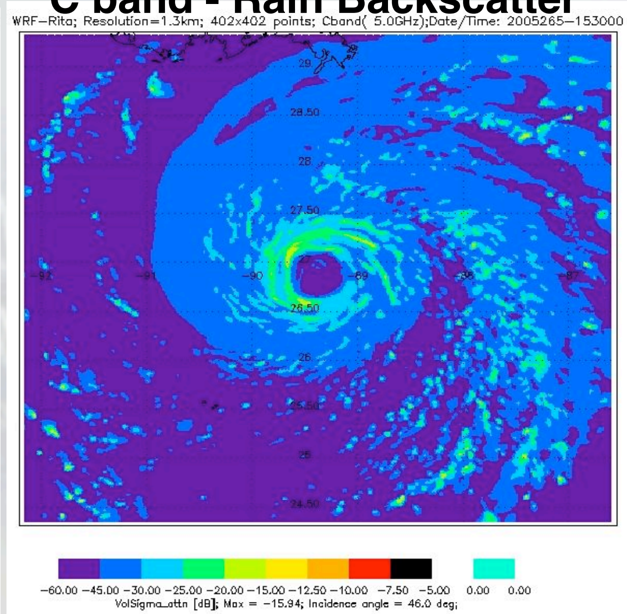
Rain Rate



KU band - Rain Backscatter



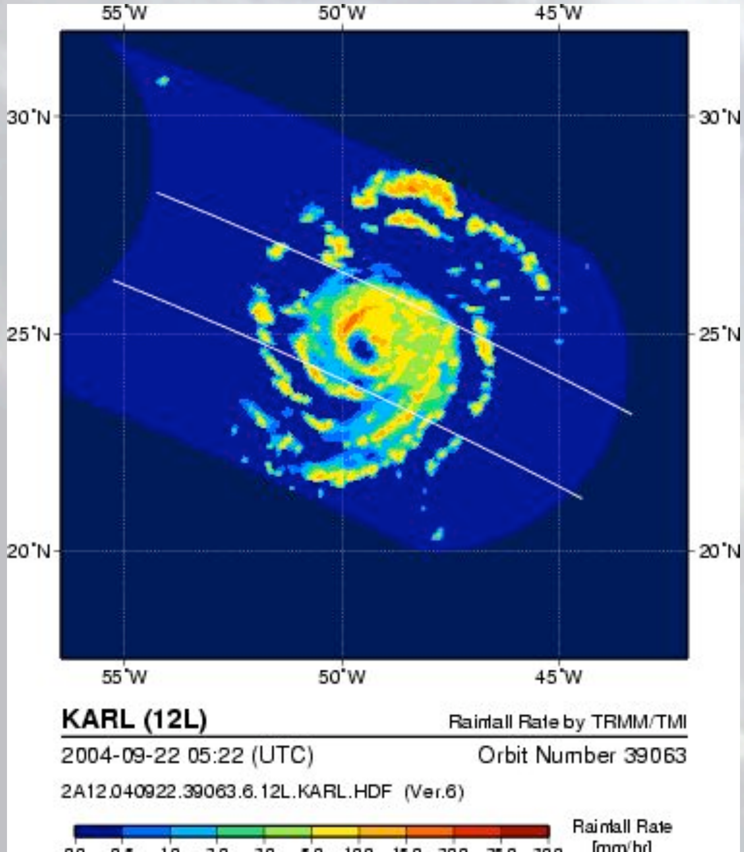
C band - Rain Backscatter

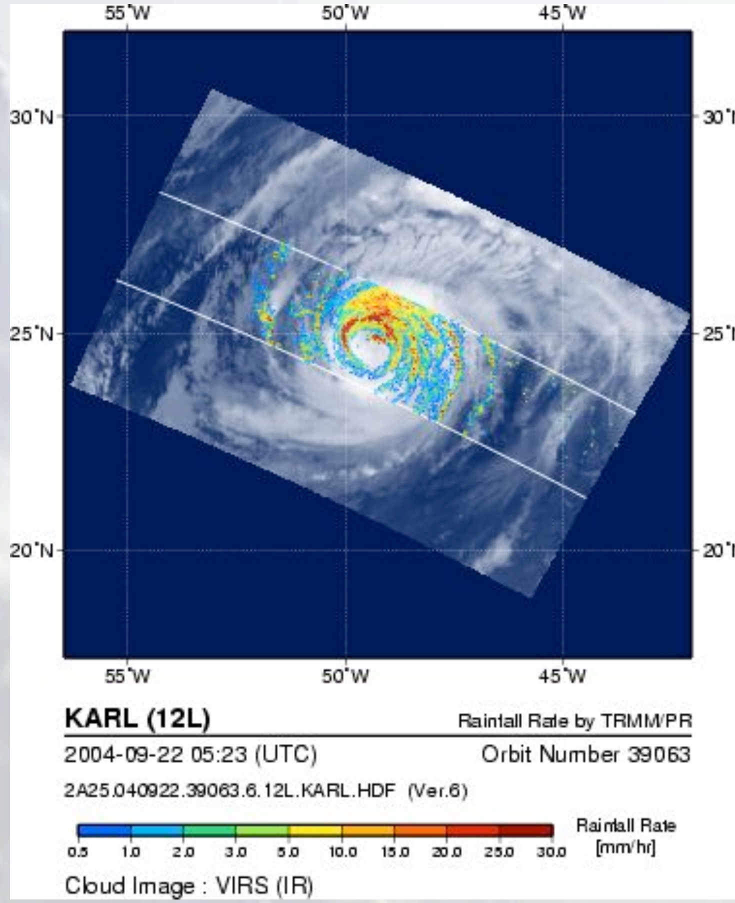


Ongoing development:

Multi-parameter Analysis
(data talk to data)

Say left panel is calculated surface R, right panel is observed R_{surf}, T_{top}:





Assimilation of R_{surf} and T_{top} requires covariance matrix of (R_{surf}, T_{top})
Assimilation of T_{top} in rain requires covariance matrix of $T_{top}| R_{surf}>0$

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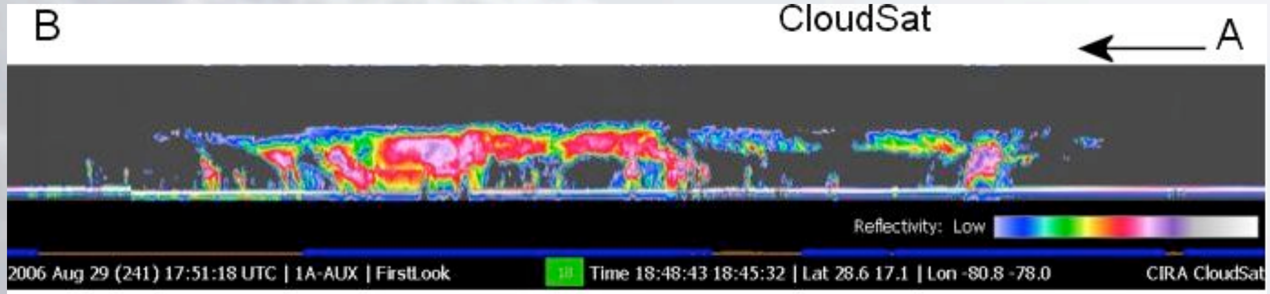
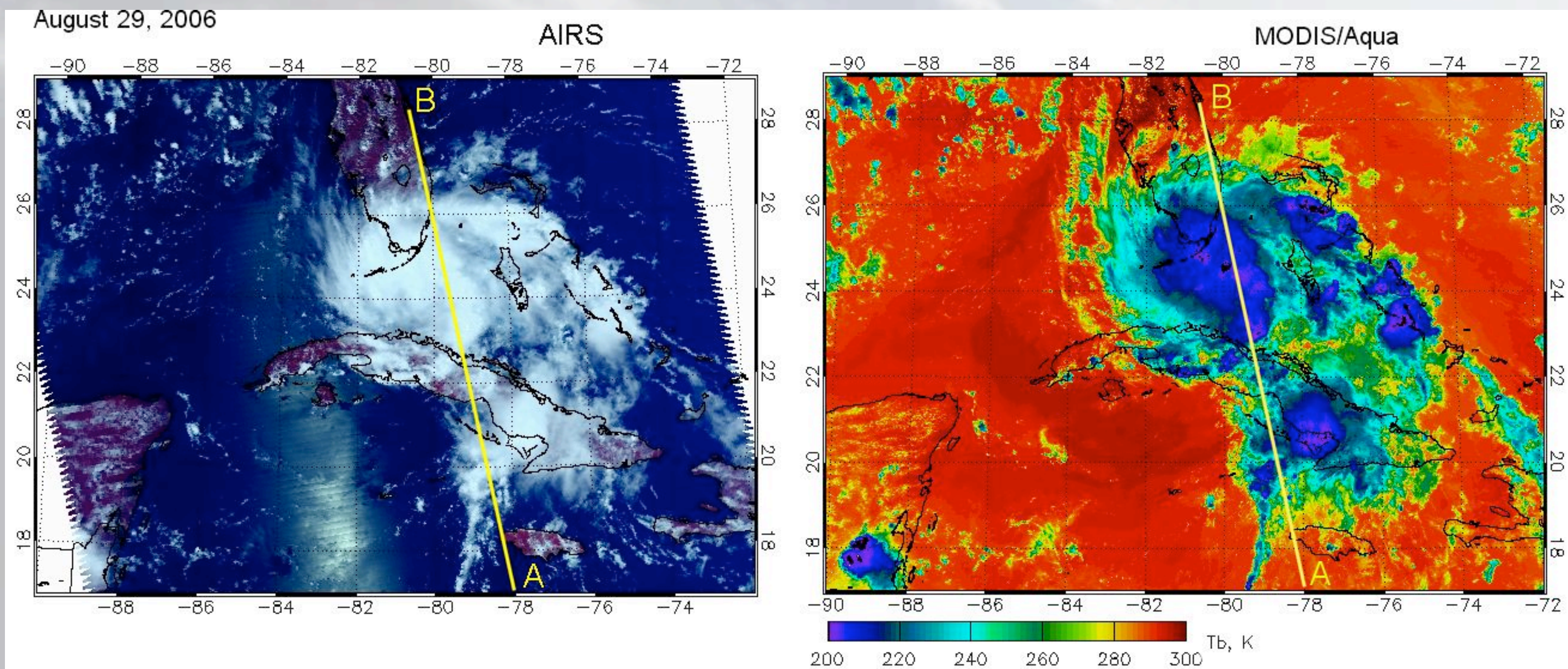
Hurricane Ernesto:





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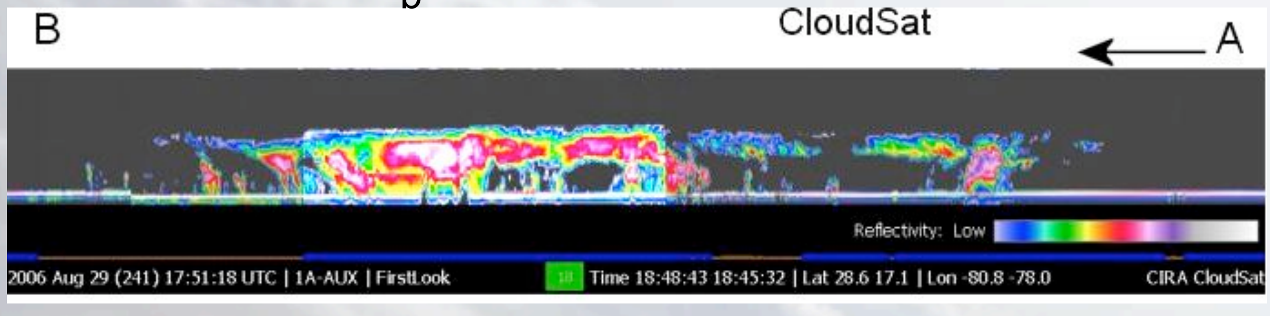
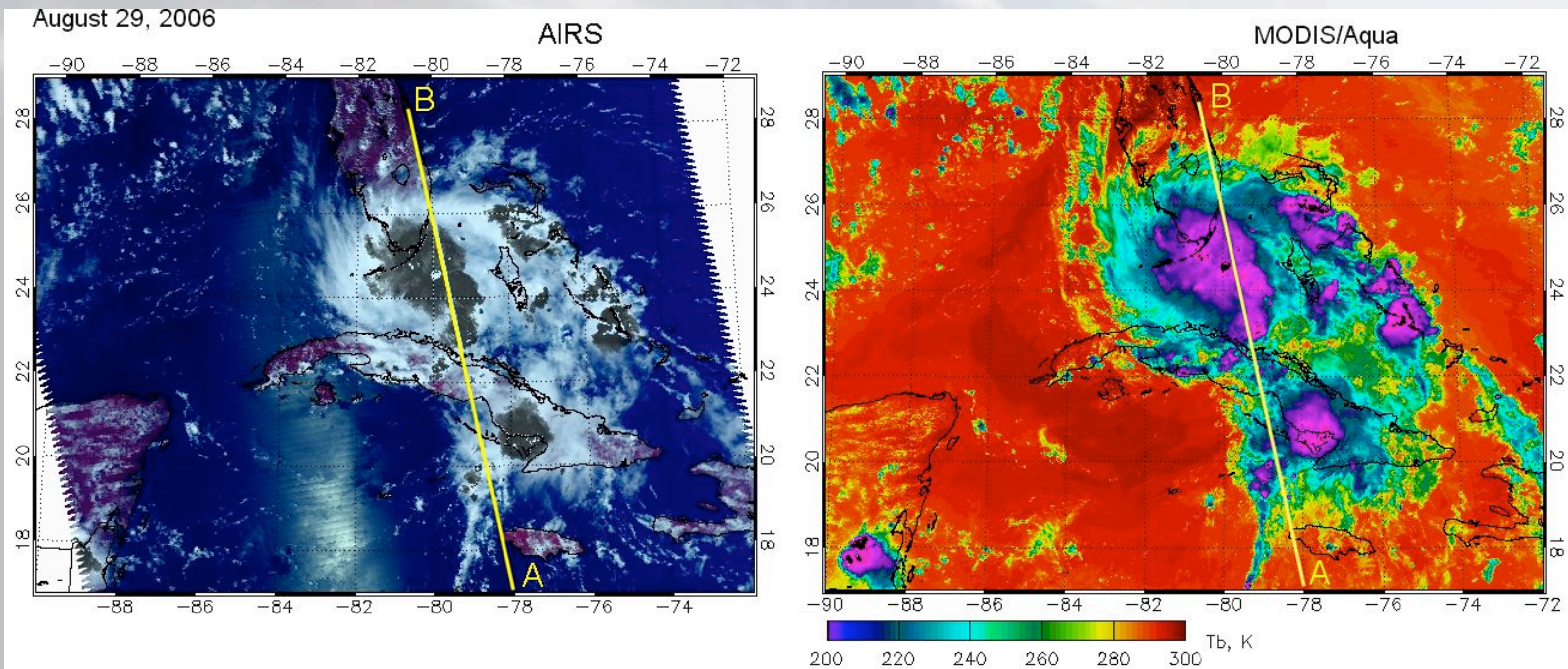
MODIS T_b < 210K:





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Summary:

- ***The developed prototype sets the framework for building a comprehensive hurricane information system.***
- ***We illustrated how WRF model simulations can be evaluated using components of the system – storm track and intensity; overall structure and evolution of the precipitation field.***
- ***We envision that the emerging information system will help*** *advance the understanding, modelling and prediction of hurricane genesis and intensity changes by providing means to diagnose and monitor the storm structure and evolution and to address the interplay between the different important processes.*
- ***Such knowledge will have impact on:***
  - **i) building and testing hypotheses**;
  - **ii) validating models** – to do that in a most scientific way we need to compare the observations to the models in terms of how they represent the hurricane structure and the relationship between multiple storm parameters;
  - **iii) providing data for assimilation** in the new generation weather models (e.g. WRF) that can assimilate and run at high resolution;
  - **iv) creating a climate record** to answer questions regarding how global warming and climate change affect hurricanes' frequency, size and intensity;
  - **v) determining what scientifically important measurements are still missing;**
  - **vi) facilitating development of new algorithms and sensors.**

Future Research & Development

- **Many Instrument Simulators to calculate derived parameters that can be directly compared with data**
- **Covariances to enable objective analysis and data assimilation**
- **Interactive, on-demand WRF modeling**
  - ***Collaborative Laboratory for microphysical parameterizations, sensitivity to model resolutions, large-scale atmospheric and oceanic boundary conditions***
  - ***Model ensembles (via GRID computing)***
  - ***3D data analysis & visualizations***
- **Data assimilation and initialization to improve predictions**
- **Hurricane OSSEs to define the next generation satellite observations**

Partnerships

- **JPL Hurricane Research Group with ~30 scientists, technologists, engineers, IT specialists**
- **External collaborators**
    - Rob Fovell, UCLA
    - Mark DeMaria, CSU, NOAA
    - Kerry Emanual, MIT
    - Mike Montgomery, NRL
    - Xiaolei Zou, FSU
    - Bob Atlas, AOML, NOAA
    - Shuyi Chen, RSMAS, Univ. of Miami
    - Robert Rogers, HRD
    - …more…
- **NOAA AOML/HRD, NHC, & Hurricane Forecast Improvement Project (HFIP)**